From the Proceedings of the Boston Society of Natural History, Vol. XIII, March 2, 1870.

ON

THE PHOSPHATE BEDS

OF

SOUTH CAROLINA.

BY N. S. SHALER.

BOSTON:
PRESS OF A. A. KINGMAN.
1870.

From the Proceedings of the Boston Society of Natural History, Vol. XIII,
March 2, 1870.

ON

THE PHOSPHATE BEDS

OF

SOUTH CAROLINA.

BY N. S. SHALER.

BOSTON:
PRESS OF A. A. KINGMAN.
1870.

PHOSPHATE BEDS OF SOUTH CAROLINA.

The following paper on the phosphate marls of the shore region of South Carolina, contains a partial account of the observations made upon this district by the author, while under the employ of the United States Coast Survey, and is published with the permission of the Superintendent of the Survey, Prof. Benj. Pierce of Cambridge. A portion of the conclusions have a certain commercial as well as scientific value, and it was deemed by the Superintendent desirable to place them before the public at the earliest opportunity. The remainder of the description of these beds will be found in the report of the work of the Coast Survey for 1870.

Physical Geography of the Phosphate Region.

The physical geography of the area occupied by the phosphate beds is so important, not only to a proper understanding of the history of their formation, but also to a right appreciation of their economic value, that it will be well to set it forth briefly before we consider the beds themselves.

The coast of the United States between the parallels of 25° and 35° north latitude, forms a shallow and very regular westward curve. The depth of this bight is about two hundred miles, and the width of the opening measured from Cape Hatteras its northernmost, to Cape Florida its southernmost point, is not far from six hundred miles.

The land which bounds this great indentation is quite level for a distance of some tens of miles from the shore, rarely rising more than seventy five feet above the tide level within this belt. The character of the shore along this great Bay of the Carolinas [1] varies very remarkably, considering the little variety of vertical relief found there. From Cape Hatteras southward for a distance of about two hundred miles, the shore is bordered by a peculiar series of low islands, disposed in the fashion of a barrier reef. Along this whole shore the sands which comprise the outer islands seem to be in constant movement, the gaps between the islands changing their positions from year to year. The observations of the Coast Survey have given very valuable data for the study of these peculiar reefs, but it is not necessary for us to examine their history. South of Cape Fear we pass beyond this system of barriers and come upon a section of shore which differs in no important regard from the usual type of low shore on which the sea is slowly gaining. This second section of the Bay of the Carolinas has a length of about one hundred miles, extending from Cape Fear to Cape Roman. The whole coast from Cape Hatteras to Cape Roman forms three great indentations. The northernmost of these, sometimes known as Raleigh Bay, is entirely formed by the narrow ridge of the sand reef which separates the ocean from the broad water of Pamlico Sound. Immediately on the south of Raleigh Bay lies Onslow Bay, which shows along the whole coast line the same structure which we find in Raleigh Bay, but somewhat less distinctly. South of the southern point of this Bay we find less and less of this barrier reef, until, as before remarked, the coast returns to the ordinary type of a low wasting shore. Continuing southward beyond this monotonous coast we find, at about twenty miles north of Cape Roman, the beginning of a new type of coast. Instead of barrier reef, with a considerable expanse of open water between it and the shore, the coast begins to be penetrated with long tide water creeks which cut up the shore region in an irregular manner. From Cape Roman to Charleston this character becomes more and more pronounced. From Charleston southwards as far as the mouth of the St. Johns River, in Florida, a distance of nearly two hundred miles, the coast for a depth of from five to twenty miles is intersected by these arms of the sea to such an extent that at many points the islands form two or three successive tiers. These tide water channels are to be counted by thousands, and vary from a few feet wide to sounds like the Broad River at Port Royal, which has a width of two or three

[1] Not being able to find any name for this remarkable feature of our continent, I have ventured to give it this one, in order to avoid the difficulties arising from the want of designation.

miles. The general appearance of such a shore is not unlike what is seen on the northern part of the coast of this Continent within the limits of what has been termed the fiord zone. The complication of outline along the Carolina and Georgia sea border quite equals any thing which can be found on the shore of Maine or Labrador. A careful comparison of the details of the topography of any region in the fiord zone with what we find on this southern coast will show some essential differences. The maps of the Coast Survey for the island region of Maine, if compared with those of the sea islands, show the features in question very clearly, and the reader is referred to them for the character of the topography of these areas, if he has not had an opportunity of studying it in the field. The most important of these differences is that the main channels of the fiord regions always run perpendicular to the shore, while in the sea islands the channels approximately parallel to the coast are more numerous than those which are perpendicular to it. It is evident that no such scouring as is brought about by glacial streams could have excavated the tortuous channels of the sea island region, for to have produced such water ways the ice currents would have had to move parallel to the shore; which is clearly impossible.

It is by no means easy to understand just how this peculiar complication of the shore has been produced, but there are some features in its structure which seem to throw a little light upon the question. Throughout the sea island region the attentive observer may see that the surface of the ground is disposed in long, wave-like undulations, the summits of which are generally parallel to the shore. On the innermost of the islands the action of the weather has partly obliterated these reliefs, but over a large part of the territory they are still quite conspicuous.[1]

On St. Helena Island they are peculiarly distinct, for the valleys between the summits of the ridges, though they are only a few feet deep, are still depressed enough to convert their bases into swamps, so that the alternation of upland and morass in parallel lines characterizes al arge part of the surface of this and the adjoining islands. It is clear, on even a casual inspection, that these reliefs are not the product of aërial erosion; their channels are rarely occupied by streams; indeed, one may travel for days among these islands without

[1] I am much indebted to Capt. C. O. Boutelle, of the U. S. Coast Survey, for information on many points connected with the topography of this region, both subaërial and submarine, and especially for having called my attention to these parallel ridges on Hilton Head Island.

seeing any indication of subaërial erosion, except from tidal currents wearing away some low cliff. There can be no doubt that this contour of surface is due to submarine forces, and that the essential features of the topography of this region were impressed upon it before it came out of the sea. Something of this same character of surface may be found beneath the level of the ocean along this coast, though it is at no point so clearly traceable as on the surface of the islands. There can be little doubt that these ridges and furrows are due to the run of tidal currents along the shore. There seems to be a tendency in streams not bounded by resisting banks, such as the tidal streams which course along a shallow shore, to arrange the material they sweep over in long ridges. Such a stream does not always press equally upon its floor, but is apt to have a banded character, or to have a form which may be compared to several streams flowing side by side, and closely joined with each other. Just what this is owing to it is not easy to say, but it seems not altogether improbable that the peculiar alternate strips of hot and cold water noticed in the Gulf Stream by the officers of the Coast Survey, may be due to the same or a related cause. The action of currents of air upon incoherent vapor in the atmosphere forming the banded clouds called by sailors *mares' tails*, may possibly be due to the same tendency.

In order to understand just how the sea acted upon this surface as it began to be lifted above it, it must be noticed that although the tides at Cape Hatteras or Cape Florida are not more than two feet in height, they steadily increase as we go nearer to the centre of the Bay, until at Fort Pulaski, at the mouth of the Savannah River, they are over seven feet in height. This heaping up of the tide in this bay may be entirely due to the usual action of converging shores upon the tidal wave which flows into the bay they form; though it does not seem as if the indentation was sufficiently deep to produce so great an effect.

If we go back to the time when this shore began to emerge from the sea, it will be seen that where the tide was of considerable height it would tend to sweep around the low islands formed by the upper part of the ridges before described, and to dig out the incoherent sands which formed the bottom of the troughs between them. As the shore gradually rose higher these water ways would be more defined; but if there was an extensive tide water surface left, the scouring action would be quite decided, and these channels might in time acquire considerable depth.

A careful reconnaissance of the shore between Capes Hatteras and Florida will show the observer that the Sea Island topography begins where the tide rises above about four feet, and becomes more and more marked as we go towards regions where the tide becomes higher and higher, or in other words, that in a general way the amount of complication of outline of the shore line is proportionate to the height of the tide.

Geological History of the South Carolina Coast Region.

The physical geography of this region affords the key to its geological history, or to that portion of it, at least, which has given it the character it has at present. But to understand the more remote history of this region we must go back to a time when the shore line was at least two hundred miles west of its present position. At the close of the Cretaceous era the shore of this southeastern border of the continent lay near to the base of the Alleghany Mountains. The uplifts at the close of the Eocene probably carried the shore line some distance to the eastward, but just how far it is not easy to say, as subsequent wearing action has destroyed a part of the record. The elevation which closed the Miocene seems to have been far greater than that which came at the end of the preceding period. It appears as if the shore line must have come at some points, especially on the southern part of South Carolina, nearly as far east as the present coast.

The last considerable change of level which this shore has experienced came at the close of the Pliocene era. It seems likely that this uplift carried the shore line much to the eastward of its present position. The whole of the sea island belt is being worn away by the ocean at a quite rapid rate. The scouring action of the powerful tidal currents which flow through the fiords between the islands, tears away a great deal of the materials over which they sweep. Along the whole sea island belt from Winyah Bay, just north of Cape Roman, to the mouth of the St. John River, in Florida, this erosive action has resulted in the production of a broad, slightly submerged table land, having an average width of about eight miles, and an average submergence of about three fathoms. This table of sands is very well shown on the sailing chart of the U. S. Coast Survey, sheet 3d. The outer part of this bank probably marks the position of the shore at the close of the last uplift; that which created the sea island region. We shall soon see reasons for supposing that this must have been an exceedingly recent occurrence in the geological sense of that word. Wherever one of the great tide water streams, such as the Edisto, the Coosa, or the Broad River, debouches into the sea, the coast chart shows that the sands swept out by it have built a delta which reaches beyond the table sands, and some distance out into the deeper water beyond.

It is very probable that the coast line was once much further out to sea than the border of this three fathom deep shoal would indicate. If the reader will attentively notice the way in which the Gulf Stream runs after it leaves the straits of Florida, he will perceive that it is thrown with great violence against a part of the coast of the Bay of the Carolinas. Its current, with a velocity of two to four miles per hour, strikes against the bottom of the sea in 31°, where the water has a depth of only one hundred fathoms. From this point nearly to Cape Hatteras, or for most of the length of the Bay of the Carolinas, this stream probably touches the bottom on its inside border.

There can be no doubt that this stream must exercise a certain wearing action against this part of the slope of the continent. A river having the velocity of the Gulf Stream at this point, or a tidal current, such as may be observed in our harbors, is capable of taking up and removing considerable quantities of detritus. Whatever erosive force the Gulf Stream may have at present, there is a great probability that in the immediate geological past its action on this shore must have been quite powerful. It has been clearly shown by Professor Agassiz that the Florida coral reefs are but the last stages in the building of that great natural breakwater, and that the whole peninsula is probably the product of the work of the existing species of polyps and acalephs, working during the last geological period. If this be so, then it follows that before the erection of the Florida mole the Gulf Stream must have swept against the shore of the Carolinas in a more direct way than it does at present. The removal of the southern half of Florida would certainly increase the violence with which the stream presses against the Carolina shore. There is, furthermore, no doubt that the region swept by the inner edge of the Gulf Stream is composed of materials calculated to wear very rapidly when submitted to the action of a current of water. Although these considerations are not calculated to give us any decided assurance concerning the part which the Gulf Stream has played in the erosion of this shore, they still make it probable that it has had no unim ortant share in the shaping of the coast.

It may be remarked, in passing, that there seems to be no clear evidence of recent subsidence on this coast. I am satisfied that the many facts which seem to indicate such action, and which have even deceived the remarkably acute Sir Charles Lyell, are really to be attributed to a variety of minor accidents, such as the undermining of the coast by the action of the waves, or to the rotting away of a considerable thickness of vegetable matter beneath the surface of the ground. This view of the meaning of these supposed evidences of subsidence is ably defended by Professor Tuomey in his report on the Geology of South Carolina.[1]

The Geology of the Phosphate Beds.

The effort to identify accurately the formations of North America with those of Europe has led in some cases to the hasty use of the names which have been applied to certain beds in the European sections, to designate American rocks.

In the nomenclature of the South Carolina beds, we have what seems to be an instance of this confusion of names. In the largest work which has yet been published on the geology of this region, the "Report on the Geology of South Carolina, by Mr. Tuomey," the tertiary rocks of the State are divided into Eocene, Miocene and Pliocene, to suit the then newly proposed classification of Sir Charles Lyell. The Eocene tertiary is described as occurring in two different regions in two widely varying conditions. In the western part of the State the section shows, first, beds of sandstone and grit; second, beds of sand, gravel, and colored clays; third, siliceous clay; fourth, silicified shells; fifth, beds of sand and iron ore. In the shore region a great thickness of tolerably uniform marls is assumed as the equivalent of this varied formation, the apparently not unreasonable view of Mr. Tuomey being, that the difference in the position of these two regions relative to the shore, has caused the difference in the physical character of the beds. The organic contents of the supposed identi-

[1] Dr. Ravenel thinks that he has recognized the phosphate beds at the depth of about sixty feet below the surface, at Charleston. If this should be verified, we would be compelled, as will be seen hereafter, to suppose that after the formation of the phosphate bed under atmospheric agencies, the shore had been depressed to the depth of at least sixty feet below its present position. It would be difficult to account for such a great subsidence at this point, while beds at a distance of nine miles to the westward have not changed their position.

cal beds in the east and west regions of the State, are as varied as are their physical features. The fossils of the buhr-stone or western beds, named in the list of Tuomey, are almost all Gasteropods and Lamellibranchiates. The general character of these shells may be accepted as rather more like the Eocene of Europe than any other member of the tertiary series there, but their horizon has been determined, not by the comparison of the resemblances of the species, but by the fact that all the species found in this association are extinct. But although there is no apparent reason to question the position assigned to the buhr-stone formation, there must be doubt concerning the position of the beds of the shore region, which are placed as contemporaneous with it. We have in the Santee beds an assemblage of fossils very different from those occurring in the buhr-stone, and containing species such as the Zeuglodon cetoides, differing widely from anything found in the latter formation.

Still further to the east we have again in the marls of the Ashley and Cooper Rivers other physical conditions, and an assemblage of fossils which it is difficult to believe could have been deposited in the same geological period as buhr-stone fossils. Nor can we suppose that the one series of rocks was deposited far inland, and the other near shore, for in the Ashley beds, as remarked by Mr. Tuomey, the character of the fossils shows clearly that they could not have been deposited far from the sea border.

There does not seem the same reason for questioning the identity of the Santee beds, and those found along the borders of the Ashley and the Cooper Rivers, that there is to doubt the identity of the age of the latter beds and the buhr-stone. The identity of the first named beds does not seem to be sufficiently proven; the contemporaneous origin of the last named is at first sight so improbable that it cannot be accepted without direct proof, which has not been presented. The level character of a large part of the surface over which these beds in question extend, makes it extremely difficult to trace by natural sections the relations of these several series of rocks. The palæontological evidence not being clear, the matter must remain in some doubt until we have artificial sections which artesian wells, tapping the abundant subterranean waters of this region, will doubtless soon give.

Overlying the Santee beds and the beds of the Ashley and Cooper Rivers, there are found at various points marls which are probably to be regarded as of a Pliocene age. This is the age assigned to them by Mr. Tuomey, and if we must make a division of the tertiary section, assigning a part to each of these three names, Eocene, Miocene, and Pliocene, there seems no reason to protest against the term. The extent of country covered by these beds is so small, and their disposition so irregular, that it seems necessary to suppose that a great amount of erosion has acted upon the surface, and that only patches of the formation as it once existed, have remained to the present day. These beds are of great value to us, however, merely as evidence of long continued exposure of the low lands of this part of the Atlantic shore.

The bed of phosphate of lime which we have been preparing to study, lies immediately on top of the "marls of the Ashley and Cooper Rivers," as they have been generally termed, though these beds are not limited to the basins of these streams. The whole of the workable material lies in a single bed, from six inches to three feet in thickness. Although it varies in its chemical and fossil components, it retains everywhere certain marked features. It is always more or less nodular; the nodules vary much in size, some being no larger than a pea, some a foot or more in diameter. These nodules contain, generally, one or more fragments of shells or corals, apparently all Eocene species, which seem to have been the aggregating points of the matter contained in the nodule. So far as my knowledge goes, there have been few, if any, nodules found containing traces of vertebrate remains. Many of the nodules show traces of wearing, not exactly what would be expected from their being rolled as by a stream, but the style of wear which comes from being stamped and trodden on. The appearance of the worn surfaces reminds me of that seen on fragments of bone from Big Bone Lick, which have been ground by the trampling of the large pachyderms and ruminants which frequented that swamp. Sometimes these nodules do not make up more than a considerable fraction of the bed, the remainder being sand, pebbles, or the marl of the character found on the bed beneath. Again, the nodules are so crowded in the bed that they are soldered together into one mass, with scarce any interspaces between the separate concretions.

Mingled with the concretions there is found a very variable quantity of fossil vertebrate remains; by far the greater part of these consist of exceedingly worn fragments of cetacean bones and sharks' teeth and vertebræ, both clearly of the same species as those found lower down in the marls in the same section. Mingled with these, but comparatively rarely found, are the bones of a fossil horse, pig, mastodon, and bones and utensils of man. These last named fossils are almost always in a state of preservation, widely different from that of the remains of the cetaceans and selachians with which they are mingled. Their appearance indicates a comparatively recent inhumation.

Chemical analysis shows us that the nodules of this deposit contain the greatest quantity of phosphate of lime, the quantity varying at different points from forty to nearly seventy per cent. The first and most natural seeming explanation of the large amount of this salt, is that it is derived from the bones and excrements of the animals whose remains are found in the bed. But the points where the most bones are found are not those where the phosphate deposit is thickest or richest. At Chisholm's Island, on the waters of St. Helena Sound, where the bed has the greatest development yet discovered, and where the analysis shows more phosphoric acid than at some of the localities the richest in bones, the remains of vertebrate animals are very rarely found. It is not too much to say that at this locality not one part in ten thousand of the mass is composed of vertebrate remains. Nor can we assume that the mass of phosphoric acid has been furnished by the decay of bones which have been utterly broken down; in that case we should have the remaining bones showing all degrees of preservation. This, however, is not the case; the fragments, though usually much worn, retain their structure very well. Although I went upon the ground with a disposition to regard the beds as the result of the decay of vertebrate remains, the general character of the deposit soon compelled me to seek some other explanation of its origin.

It has been suggested by a distinguished chemist that the deposit was the result of the submergence of a great guano area, during which submergence the bones of marine animals became mingled with the mass. There are several objections to this view: in the first place, no remains of birds have been found in the deposit, though fossils quite as likely to be destroyed, are well preserved there. Then it is difficult to see how in the immediate past this swampy shore could have been the breeding place of the quantities of birds which would have been required to have accumulated these phosphates, nor could we suppose that the climate of this shore could have been at the time of the deposition of the phosphates so different from what it is at present, as would have been required to produce the dry conditions essential to the accumulation of a guano deposit.

There is another view of the origin of these phosphate beds, which, so far as my knowledge goes, has not yet been suggested, and which, it seems to me, solves a part of the difficulties.

The phosphate layer rests upon a mass of marl containing a number of fossils which are found in a worn condition mingled with the phosphate nodules. The analyses of Dr. St. Julien Ravenel have shown that at several points beneath the phosphate beds the marl contains several per cent. of phosphate of lime, and it may be assumed as eminently probable that the whole of the marl beneath the region where the phosphate beds occur, contains a certain quantity of this material, mingled with the carbonate of lime which constitutes the mass. Now it is a well known fact that water containing carbonic acid gas in solution has a solvent action upon both these salts of lime, but that its power is greatest on the carbonate of lime. So that a mass of marl containing both these materials, submitted to the action of water charged with carbonic acid, might have the carbonate of lime entirely removed, and the mass left behind when the solving action ceased, might consist almost altogether of the phosphate of lime.

If we look a moment at the conditions which prevail in the phosphate region, we shall see that with this view we can easily frame an explanation of the formation of this phosphate layer. The usual section through these beds gives us on top a layer of vegetable matter and soil containing humus, through which the water percolating becomes charged with carbonic acid; then the phosphate layer; immediately beneath that the marl containing phosphates, which is only slightly permeable to water. Soaking over this marl the water becomes charged with carbonate of lime and some phosphate which it carries away in the drainage system of the country. This process, going on for centuries, gradually dissolves away a great thickness of the marl, and gives, as in the capping bed, an accumulation made up of fossils from the wasted beds, which resisted decay, and could not be washed away; of phosphates which became aggregated into nodules; of remains of man and other recent animals, which, falling in the swamp, sank through the soft bog and became trampled in among the nodules by the living animals which inhabited this low land.

Great freshets might lay down several feet of clay and sand, or some rearranged marl on top of the phosphate layer, thus confusing the record, by making the remains of man and extinct animals associated with his early history in this region, seem a part of the ancient marl beds.

Looking upon the phosphate layer as the debris of a large amount of eroded marl, it is no longer a difficult matter to account for the association of fossils found there, which would be inexplicable without some theory of this kind.

Although this view of the derivation of the phosphate beds capping the Ashley River marls seems to clear away a part of the doubt which hides their origin, it discloses another question which is about as difficult to settle. If we are to derive the phosphates from the marl, in what manner are we to account for the presence of this material in the latter beds? I cannot say that I feel any great satisfaction in the explanation which I am about to offer, which after all is only half an explanation; but inasmuch as it promises to cast some light on what is a rather dark subject, I venture to present it.

It may be premised that the whole question of the formation of phosphates is one of the little understood provinces of geological inquiry. The usual supposition of the vertebrate origin of these accumulations does not fit some of the most conspicuous examples, and the ingenious hypothesis of the able chemist and geologist, Mr. T. Sterry Hunt, which accounts for the origin of the massive apatite beds of the early palæozoic by the action of quantities of unarticulated Brachiopods, separating phosphate of lime from the water of the sea, though doubtless a true cause, is not competent to explain many cases of the occurrence of materials containing phosphoric acid in some of its combinations.

The tolerably uniform dissemination of phosphate of lime through the marl beneath the phosphates cannot be explained on any theory of the formation of such deposits that has come under my observation. The general character of the marl underlying the phosphates is quite different from what would be supposed from the fact that it contains numerous vertebrate remains. It does not seem to have been a deposit formed near the shore, but rather to have been the product of those agents of deposition which work in the deeper parts of the sea. It was my good fortune to see some of the material brought up from the floor of the Gulf Stream between Florida and Cuba, from a depth of nearly two hundred fathoms; the resemblance of the general character of this material to the marls beneath the phosphate bed is quite striking. It is by no means improbable that at the time when these beds beneath the phosphate bed were being accumulated, the Gulf Stream flowed over them. The peninsula of Florida did not then exist, and the natural path of the stream must have been just over the region of the Ashley River beds.

The material brought up by the Coast Survey dredging work under the direction of Count Pourtales, consisting, as has just been stated, of a marly substance, resembling in a general way the marls of the Ashley and Cooper Rivers, has recently been subjected to analysis, and strange to relate, it, too, contains a considerable amount of phosphoric acid. The analyses are not yet complete, but will in due time be made public by the officer having these dredgings in charge; but enough is known to make it sure that the chemical character of the material now accumulating on the bottom of the Gulf Stream, is likely to show a surprising likeness to that which was laid down on the sea floor where the Ashley and Cooper Rivers' beds were formed.

It is not the least singular part of the likeness of the materials on the Gulf Stream floor to the beds beneath the phosphates, that there, too, vertebrate remains abound. The dredge of Count Pourtales brought up from the bottom of the stream a considerable number of fragments of the bones of the dugong, or some allied animal. It might at first sight seem as if the occurrence of these bones afforded a sufficient explanation of the presence of phosphoric acid in the material composing the floor of the Gulf Stream, but here, as on the Ashley and Cooper River marls, it would be necessary to suppose that a large part of the sediment falling on that floor (probably at least one third of the mass) was the product of vertebrate animals. This is clearly by no means a probable supposition.

We know that some of the pteropod mollusks, forms which are frequently abundant in the ocean at great distances from the land, have a composition not materially different from that of bones. It has even been stated, though I do not yet know by what authority, that some of the marine algæ contain a large per cent. of phosphate of lime. The fact of the existence of this material in a number of the inferior organizations of the sea makes it, in most cases, more reasonable to account for the formation of extensive masses of phosphate beds by the deposition of the remains of invertebrate species, than to suppose that they were accumulated by vertebrate animals.

If the foregoing view of the process by which the phosphate beds of South Carolina were formed be correct, then we may draw the important conclusion, important at least in an economic point of view, that wherever the phosphate-containing marls of the South Atlantic sea board lie in a position similar to that which they occupy in the vicinity of Charleston, the bed of nodular phosphate is likely to be found. The United States Coast Survey is about undertaking a careful examination of the region where it is likely that these beds may be found. So that this important source of wealth, not only to the States where it occurs, but to the whole country, may not want for that aid in its development which it may reasonably be expected the government should give.

There can be no doubt that the area of the nodular phosphates is much underestimated, though how great a part of the region where they occur contains the material in workable quantities, may remain a questionable matter.

It seems likely that the peculiar advantages of these beds will enable them for a long time to control the market for phosphates, at least in this country. They are over great areas, scarcely covered by the soil, so that the labor of excavating is small. The beds are, in most cases, remarkably accessible, on account of the peculiar system of lagoons which intersect the coast. Furthermore, the supply lies in a region which, more than any other in the world, is likely to require a large amount of fertilizing material of this character, to balance the waste brought about by the exportation of raw agricultural products.

NOTE. — It is a pleasure to me to acknowledge my obligation to Dr. St. Julien Ravenel for the great assistance kindly rendered by him during my examination of the South Carolina beds; he, having been the first to see the commercial value of these beds and a constant student of their features since their discovery, is now the person best acquainted with their phenomena. I account it a very fortunate thing that I had his guidance over a considerable part of the region I traversed.